

## **Creativity, Conformity and Constraints**

### **A Grounded Theory Study on Capstone Group Design Projects**

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## **INTRODUCTION**

Numerous definitions of creativity exist, however, Daly et al. have suggested that creativity is “a type of novel thinking, where people redefine problems, see gaps in knowledge, generate ideas, analyse ideas, and take reasonable risks in idea development” [1]. From this definition we can deduce that creativity skills are intertwined with one’s ability to solve problems. In undergraduate engineering courses, however, there exist a multitude of barriers for students

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to develop these creative skills for solving engineering problems. Learners tend to be viewed as passive receivers in traditional teaching methods. The shift to a student-centred paradigm, the learner now viewed as an active agent in his or her learning, has resulted in development of problem-centred pedagogies such as problem-based learning and Project-Based Learning (PBL). De Graff & Kolmos state that “Project work is problem-based by definition” [2], hence studies on PBL offer valuable insight into creative skill development.

As delivery of PBL varies substantially there exists a pressing need to conduct in-depth studies of deliveries to analyse the student experience. There are many publications that consider competencies and perceptions in the form of surveys and statistical researches. Outcomes of these studies suggest that creative “problem solving is the core of engineering practice” [3], however, these are still developed in the context of an academic setting. Paretti (2008) has suggested that there exists, in the student experience, a tangible dichotomy between the simulated workplace and the educational constraints of project work [4]. This idea is echoed by the Institute of Chemical Engineers (IChemE) who recognise that educators are working under academic constraints when delivering such projects [5].

## **1 PROJECT-BASED LEARNING**

De Graff & Kolmos (2014) argue that new educational pedagogies, such as PBL, emerged from the change in nature of the relationship between the University and wider society towards one where the former holds responsibility for addressing the societal “need for engineers with relevant skills, and competencies” [6]. This conclusion carries substance with many accrediting bodies of engineering programmes introducing criteria that aim to meet the needs of industry.

According to Prince & Felder (2006), PBL can be formulated as “[beginning] with an assignment to carry out one or more tasks that lead to the production of a final product – a design, a model... The culmination of the project is normally a written and/or oral report summarizing the procedure used to produce the product and presenting the outcome” [7]. Thus, PBL exemplifies active learning in that it “involves students in doing things and thinking about the things they are doing” [8]. Often team-based, PBL presents an opportunity for students to develop other social skills for collaboration, such as communication and teamwork. PBL can be both formative, as a regular activity throughout a programme, or as a summative, capstone element that offers consolidates at the end of a programme.

### **1.1 Capstone Group Design Projects (CGDP)**

Group Design Projects (GDPs) are characteristic to Chemical and Process Engineering (CPE) undergraduate programmes worldwide and are generally applicable to many engineering disciplines. GDPs are potential platforms to assist students’ development of professional identities as these can simulate the workplace. For CPE specifically, GDPs must take place as a capstone element of undergraduate degrees, as per the requirements set by accreditors, such as the IChemE. A Capstone GDP (CGDP) potentially offers one of the final interactions students have with education prior to employment. Unlike the limited timeframe involved in traditional lectures, tutorials or even problem-based learning, PBL typically lasts months.

## **2 CONTEXT FOR THE STUDY**

This study examines CPE undergraduate cohorts at the University of Strathclyde. Originally founded in 1796, the University of Strathclyde (UoS) was established for the education of practical disciplines, hence the motto “the place of useful learning”. Engineering, a vocational

subject, has been at the heart of the university with just under six thousand students enrolled as of Autumn 2017. The first Chemical Engineering syllabus at UoS ran in 1870.

## 2.1 CGDP with Chemical and Process Engineering (CPE) at UoS

The CPE department has been an official part of the university since it gained its Royal Charter in 1964. CPE here has grown significantly over the last decade with an undergraduate intake that has increased significantly, more than doubling from 56 students in 2004 to 115 in 2015.

Characteristic to CGDP in the CPE department is the allocation of a small number of student groups (2-3) to an academic member of staff who acts as a supervisor and evaluates accordingly. Students and staff are provided with the same design brief which includes the problem statement to be addressed by all groups.

Table 1. CGDP delivery at the UoS CPE department and its supervision and assessment development over time

|                      | 2015                  |                   | 2016 & [2017]              |                      |                                | 2018                       |  |
|----------------------|-----------------------|-------------------|----------------------------|----------------------|--------------------------------|----------------------------|--|
| Approach             | 2 concurrent projects |                   | Single 3-phased project    |                      |                                | Single 2-phased project    |  |
| Projects/Phases      | Detailed design       | Conceptual design | Feasibility /scoping (P1)  | Detailed design (P2) | Economics /sustainability (P3) | Feasibility /scoping       | Detailed Design & economics/sustainability |
| Duration in Weeks    | 12                    | 12                | 4 [4]                      | 4 [5]                | 3 [2]                          | 4                          | 7  |
| Supervisors          | 7                     | 9                 | 6 [7]                      | 10 [11]              | 6 [7]                          | 18 (2 per group)           |  |
| Students             | 104                   |                   | 111 [112]                  |                      |                                | 131                        |  |
| No. of Groups + Size | 18 (5-6)              | 18 (5-6)          | 16 (6-7)                   |                      |                                | 19 (6-7)                   |  |
| Assessment Type      | Individual            | Individual        | Group                      | Individual           | Group                          | Group + Individual         | Individual (+ Group HAZOP)                 |
| Assessment (%)       | 66.7%                 | 33.3%             | 26.7%                      | 40%                  | 33.3%                          | 30%                        | 70%  |
| Assessable Outputs   | Report                | Report            | Report & Oral Presentation | Report               | Report                         | Report & Oral Presentation | Report                                     |

The CGDP has undergone significant changes in the recent past (see *Table 1*). For many years, the CGDP ran as two distinct projects undertaken simultaneously. From 2016 the CGDP was delivered as a single project with a phased approach. In 2016 and 2017, it consisted of three sequential stages focusing on Feasibility and Scoping (P1), Detailed Design (P2) and an economic and sustainability analysis (P3) respectively. P1 and P3 involved group assessment and were supervised by one staff member and the individually-assessed P2 was supervised by another. 2016 onwards, CGDP also differed to prior years, as each group were now given different locations and capacities in their problem statements.

In 2018, P2 and P3 were combined into a single phase thus the CGDP became two-phased. During this iteration of the CGDP, the supervision involved a pair of supervisors who saw the group through the project.

### **3 RESEARCH METHOD**

#### **3.1 Grounded Theory**

Malmi et al. (2018), in their meta-analysis of research methods, suggest that the majority of Engineering Education (EE) research employs “data analysis methods [that] are simple descriptive statistics or simple/undocumented qualitative research methods”. The same authors “encourage authors to consider adopting more elaborate methods, both quantitative and qualitative” as a concluding recommendation. [9]

This research utilises a Grounded Theory (GT) research strategy, with the CGDP at the UoS’s CPE department as a primary case. GT offers a novel but rigorous approach with the principal function of developing an unbiased theory built upon empirical evidence. Further, as the CGDP was to undergo changes in delivery, a method that could account for variability was needed and GT not only allowed for variability to be introduced in the study but necessitated it for validity of the resulting analyses.

GT was developed by Glaser & Strauss (1967) from their work on terminally-ill patients [10]. The chief motivation of the authors was to address biases in traditional social research, emerging from researcher preconceptions and the ‘forcing of theory upon data’. Hence, traditional GT remains distinct as a formal research strategy as it rejects literature reviews as a pre-requisite to research. Instead, GT relocates the primacy of the literature review to the closing stages of research as the literature becomes another source of data for analysis.

GT employs varying methods to ensure the developed theory fits the data. The initial focus of the method is to remain open to the possibilities of the study in the substantive area, CGDPs in the case of this research, and thus explore variability. From the onset of data collection, analysis proceeds immediately in parallel. In this way, data collection informs analysis and vice-versa. As the developing theory becomes increasingly robust, theoretical sampling takes place, a technique by which gaps in the theory are addressed. Active pursuit of appropriate conditions and incidences that address evident gaps and even contradict the theory adds further robustness to validity.

#### **3.2 Research Questions**

The research questions underpinning this study were open, as the aim of the study was to determine what actually occurs during CGDPs and to explore the phenomena of CGDPs in an EE context. The research questions were formulated according to the principles of GT.

- What are the main concerns of students and staff participating in CGDPs?
- How do participants in CGDPs resolve and process these concerns?

#### **3.3 Data Collection**

Three iterations of CGDP (2016, 2017 and 2018) have been investigated within CPE at UoS. As per the GT dictum “all is data” [11], data collected for analysis varied in format. Project briefs (or problem statements) were collected as examples of guiding documentation provided to all students and staff. Written field notes and audio recordings of observations were made of weekly supervisory meetings: a total of 87 observations of 12 groups over two iterations (2016 and 2017) of the CGDP, were observed. The most theoretically-rich data collected were

audio recordings and subsequent transcripts of 27, semi-structured, in-depth interviews with both students (n=17) and staff (n=5). All transcripts were pseudo-anonymised to protect identities and here our analysis builds largely on the examination of interview transcripts from the 2017 CGDP participants.

### 3.4 Data Analysis

The presented discussion builds upon the process of incident-by-incident comparison as an analytical method for concept generation. Glaser & Holton (2004) suggest that the researcher begin analysis by asking questions to the data including “What is this data a study of?”, “What [conceptual] category does this incident indicate?”, “What is actually happening in the data?”, “What is the main concern being faced by the participants?” and “What accounts for the continual resolving of this concern?” [11]. As suggested by Charmaz, the initial data was analysed line-by-line and coded with gerunds (italicised in the analysis) to bring to light the social processes accounting for students’ behaviours [12]. By questioning the data in this manner and comparing incidents, higher level concepts are formed and then further developed from repeated comparison with incidents and the emerging concept.

## 4 DISCUSSION

Although a wealth of significant concepts emerged from the data, discussion focuses upon two concepts, *conforming* and *constraining*, that are particularly relevant to student creativity.

### 4.1 Conforming

The social process of *conforming with peers* (*conforming*) emerged from incident-by-incident analysis as significant to students’ experience of the CGDP, represented in Fig. 1.

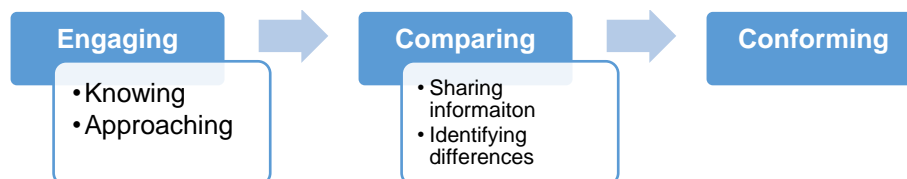


Fig. 1. *Conforming with peers* and its sub-processes

The significance of this phenomenon was deduced from a high frequency of reported incidents from student interviews, either in the first or second person. These were initially composed of fragmented codes which were then compared to form *conforming with peers* as a substantial category. Thereafter, questions addressing this process were introduced to subsequent interviews where *conforming* was absent otherwise, ultimately revealing conditions by which the social process comes about.

This process of *conforming* was a significant behaviour employed by students at the onset of the individual phase (P2) but was also reported during the group phases too (specifically, P1). The following discussion relates to individual phases (P2) unless specified otherwise. One of the conditions for the process of *conforming* to take place was students *engaging with similarly-tasked peers*. A pre-requisite to *engaging* was simply *knowing of similarly-tasked peers* without the need to have any significant prior acquaintance:

“...he got a Facebook message through from somebody who have not really spoken to at all, don’t really know any of their friends either... “All right, they’ve done this, I’ll try that.” – Cain Bruce (E1)

The above pseudo-anonymised extract suggests that prior interaction was not a necessary component in the decision about who to approach. Different media of *approaching* became

apparent too, ranging from students using online social media platforms to meeting informally with one another.

*“Sometimes I’ll meet people who are from different groups who are doing something similar, we’ll have lunch and stuff together and talk about the ability to....” – Cain Bruce (E2)*

Notably, there was a high frequency of self-reporting of the formalisation of such groups into autonomous learning groups (ALGs), contingent on task similarity. In many instances students reported these directly, as is the case for Natasha Douglas:

*“... the individual phase, there was people doing similar things to you, so you’d work with them.” (E3)*

The extract suggests that such behaviour was considered normative and the condition of similarity is what bound such groups together. Indeed, the same interview participant went on to retell her own account of leaving such a group upon losing the condition of similarity: *“So I was doing a different – they were all doing [equipment] in stage 1 and I was doing it in the second stage. So, I wasn’t dealing with the same thing as them.”* Other interviewees who did not join an ALG ascribed this to a lack of similarly tasked peers.

ALGs emerged as having properties distinct from original groups as these groups shared the same task, unlike original groups which involved differing sub-tasks. ALGs were self-selected and non-enforced, hence viewed favourably by students with students, such as Ellis Donaldson, describing these as *“...good, that was great”* (see also E5).

*Engaging* takes place for *comparing* to take place, the primary purpose of which is in *verifying one’s work*. *Comparing with similarly tasked peers* involves both *sharing of information* and *identifying differences*, both of which can be understood from the following extract.

*“...he was like, “how did you manage to do that?” ... I just sent it to him and I was like “let me know if you notice anything that’s wrong with it.”... at least I’m getting something back” – Will Ross (E4)*

Will Ross, a student who did not participate in an ALG, indicates how he was approached by a similarly tasked peer during P2. Multiple students experienced compulsions to share information upon requests from peers. In ALGs, sharing of information was expected of members and discussions would revolve around reaching collective agreement on design decisions:

*“It was quite good working in this group because you’d come up with an idea and somebody would challenge it... I don’t really know if I did it completely by myself, how far I would have gotten... And then you’re completely wrong because nobody has really challenged you. – Natasha Douglas (E5)*

Where ALGs promoted a form of instant-feedback and verification for students by the function described by this extract, those students who did not join an ALG faced the problematic situation of obtaining feedback by other means. Most individuals opted for re-establishing a connection with members of their originally assigned group.

Importantly, the feedback provided by supervisors was deemed inadequate as the supervisor was both guide and evaluator therefore some students suggested a fear of being evaluated negatively during these interactions by disclosing issues or raising questions:

*“I just get quite stressed when I have to ask the supervisor a question. Because maybe this is something I should know – are they going to give me in to trouble.” – Natasha Douglas (E6)*

After sharing information, a student comes to *identifying differences* where they are subject to a significant social pressure to account for these differences and must decide whether they will conform the standard of the collective.

*"I think it's a sad situation where – within myself, when I'm thinking of making this design as original to myself as I can be – I feel like I'm putting myself at a disadvantage. When I feel like I want to design this entirely on my own, and come up with all my own, work it out on my own – do it all me – part of me is like "no one else is doing that and they are all going to do better than you because they're all going to have the same method." – Cain Bruce (E7)*

Conformity is well-documented in the literature however, in organisational theory there exists the theory of "mimetic isomorphism" which can be viewed as a cautious strategy to ensure an organisation remains competitive by imitating competitors [13]. This process is reflected in the case of CGDPs, where conforming becomes a safer approach for students as there is the fear of challenging the position and views of the perceived collective. *E7* reveals the extent of the social force exerted on individuals seeking creative originality – they must not only embrace the dangers of distinction but deal with internal conflicts arising from comparisons with peers. Interestingly this phenomenon, with the same conditions, were observed in group phases too.

## 4.2 Constraining

Another concept emerging from student interviews that proved relevant to creativity centres on restrictions in the form of word and page limits, as mentioned by a staff member.

*"possibly larger, give them more space to show off. And even more space to be creative, definitely – to come up with new ideas and appreciate that in the marking – the grading scheme." Courtney Murphy (E8)*

While these limitations were introduced to simulate professional communication practice, and students understood the underlying logic, *constraining one's design* became a strategy to meet these limitations by *simplifying one's design*. Often this involved a loss of creative solutions and considerations as mentioned in *E8* and reflecting findings like that of Paretti [4].

## 5 IMPLICATIONS FOR PRACTICE

The formation of the aforementioned ALGs is of interest for educators in engineering as these were viewed favourably by interview participants, for their shared goal and social support. However, co-ordinators of CGDPs must be aware of student forming ALGs to ensure more accurate assessment measures for individual performance, such as a viva. Introducing greater variability in problem statements for groups will encourage fewer instances of conformity and thus encourage development of creative problem-solving skills but must be balanced with fair and objective assessment. The combined roles of supervisor and evaluator needs to be considered carefully as this potentially acts as a barrier to supervisor-student communication. Finally, communicating assignments must be designed by engineering educators to ensure appropriate encouragement of creative solutions.

## 6 FUTURE WORK

Staff experience, focusing on assessment and communication with students, will be explored with additional interviews and analysis. To obtain further understanding of CGDPs and student experience and behaviour, a UK-wide survey of CPE departments will be conducted to explore significant variables pertaining to the design of CGDP activities.

## 7 ACKNOWLEDGEMENTS

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